NAVAL MACHINERY
1946

PART I

NAVAL BOILERS

PART II

NAVAL STEAM TURBINES

PART III

NAVAL AUXILIARY MACHINERY

PART IV

NAVAL RECIPROCATING STEAM ENGINES

UNITED STATES NAVAL ACADEMY
ANNAPOLIS, MARYLAND

ACKNOWLEDGEMENTS

While the major work of revision of this text has been accomplished by the officers attached to the Department of Marine Engineering, valuable assistance was rendered by the manufacturers named herewith.

Many of the figures in the book were made from illustrations furnished by these manufacturers. In addition they supplied descriptive matter and offered suggestions which made possible the completion of the book in its present form.

Acknowledgement is therefore made to the following:

Allis-Chalmers Manufacturing Company
Automatic Temperature Control Company, Incorporated
Babcock and Wilcox Company
E. B. Badger and Sons Company
Bailey Meter Company
Blackmer Company
Buffalo Meter Company
Combustion Engineering Company, Incorporated
Crane Company
Crane Packing Company
Crosby Steam Gage and Valve Company
DeLaval Separator Company
DeLaval Steam Turbine Company
Flexitallic Gasket Company
Foster Engineering Company
Foster-Wheeler Corporation
Garlock Packing Company
General Electric Company
Goetze Gasket and Packing Company, Incorporated
Griscom-Russell Company
Harrison Radiator Division, General Motors Corporation
International Nickel Company, Incorporated
Johns-Manville
Kingsbury Machine Works, Incorporated
Leslie Company
Lucian Q. Moffitt, Incorporated
Manning, Maxwell and Moore, Incorporated
Northern Equipment Company
Prescott Company
Sharples Corporation
Skinner Engine Company
Star Brass Manufacturing Company
B. F. Sturtevant Company
Swartwout Company
Todd Shipyards Corporation (Combustion Equipment Division)
Westinghouse Electric Corporation
Worthington Pump and Machinery Corporation
Yarnall-Waring Company

Indebtedness is expressed particularly to the various technical sections of the Bureau of Ships which rendered invaluable assistance in editing the manuscript and to the Training Aids Development Center which produced the art work for the illustrations.

Acknowledgment is made to the Society of Naval Architects and Marine Engineers for permission to use drawings which appeared in *Marine Engineering* in a paper "Reduction Gears," written by Mr. C. R. Waller and Mr. A. Peterson.

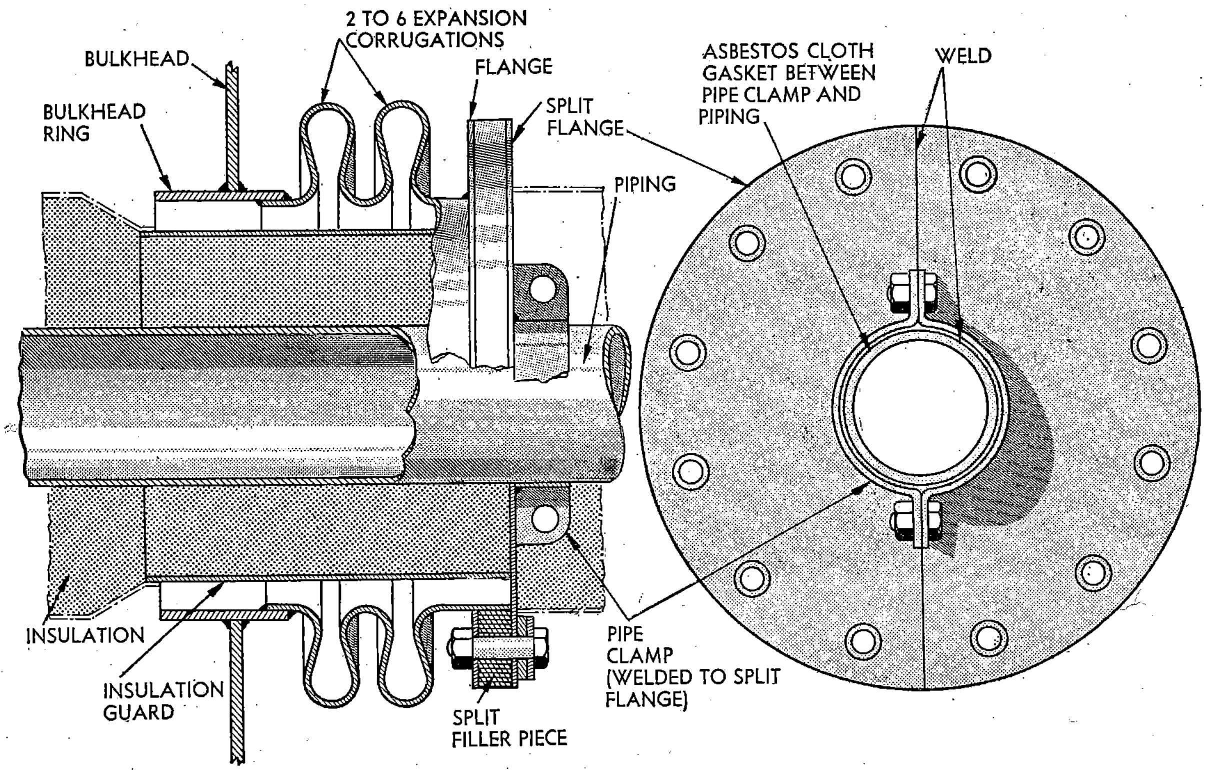


FIG. 1-8. Bulkhead Expansion Joint for Main Steam Piping.

1-5. VALVES—GENERAL.

It is often necessary to stop or control the flow of a fluid, into, through, or from a pipe line. This is accomplished by means of a valve; a device consisting of a body containing an orifice with a suitable means of tightly closing the orifice by closing a valve disc, or plug, against a seating surface surrounding the orifice. The various types of valves described below will illustrate this point.

There is a great diversity in valve design because of the wide range of fluids handled, the variety of conditions such as pressures and temperatures, and the variety of automatic features required for special purposes.

1-6. THE STOP VALVE.

In this type of valve the closing member (disc or wedge) is moved on or off the seat by the motion of an attached stem.

Stop valves may be of either the "gate," "globe," "piston" or "plug cock" type.

(1) Gate valves. This type, illustrated by *Fig. 1-9*, is used when straight line flow is desired, without throttling requirements. When the valve disc (or gate) is wide open there is little resistance to flow and a minimum of pressure drop. The gate type valve is not suitable to a throttling operation as the velocity of flow against a partially opened wedge can cause chattering, damage to seating surface and undesirable erosive effects called "cutting."

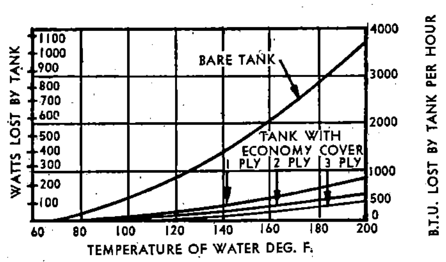
If the valve is so designed that the stem is restrained from turning, and is threaded into the hand wheel (or its bushing), the stem will be raised or lowered when the wheel is operated. The valve, then, is known as a rising stem, outside screw-and-yoke type. This type of gate valve is illustrated in *Fig. 1-9 (a)*. Sometimes the valve is designed so that the wheel and stem both rise as the wheel is turned; the stem being threaded into the bonnet. It is then known as a rising stem, inside screw type. When the stem rotates in the bonnet, but is restrained from rising or lowering, and is threaded into the gate, as shown in *Fig. 1-9 (b)*, so that the gate goes up or down when the wheel is turned, the valve becomes a non-rising stem type. However, regardless of the valve type, the valve stem type or the arrangement of any remote operating gear, the threads on the stem

CHAPTER 2

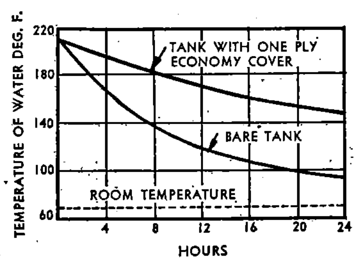
PACKING AND HEAT INSULATING MATERIALS

2-1. GENERAL.

Insulation, from a thermal standpoint, means presenting a barrier to the flow of heat. Its purpose is, therefore, to obstruct the flow of heat to or from machinery units, heat which would otherwise be absorbed or dissipated by radiation, convection, and conduction. Specific reasons for installing heat insulation on naval vessels would include one or any combination of the following: (a) conservation of fuel or boiler capacity, (b) control of temperature, (c) reduction of the temperature gradient in equipment to reduce the thermal stresses, (d) prevention of condensation, and (e) protection of personnel.



LOSSES FROM UNCOVERED 30-GALLON GALVANIZED IRON TANK AS COMPARED WITH LOSSES FROM SAME TANK INSULATED WITH AVERAGE ROOM TEMPERATURE ASSUMED AT 68°F.



COOLING RATE OF 30-GALLON TANK, 12" DIAM. 60" LONG, INSULATED, COMPARED WITH THAT OF A BARE OR UNCOVERED GALVANIZED TANK

FIG. 2-1. Curve Showing Effect of Insulation upon Heat Loss in Tanks.

Figure 2-1 illustrates the difference in heat loss from a small tank in the low temperature range in an insulated and non-insulated (bare) condition. It is at high temperatures, however, where it is vitally important that the flow of heat from units be restricted. It will be noted from *Fig. 2-2* that a bare pipe with a temperature of 200°F., under still air conditions, will lose 300 B.t.u. per square foot per hour, while at 400°F. the loss will be 1025 B.t.u. per square foot per hour, or over three times as great. The other curves show graphically the efficiency of modern insulation materials for units containing steam at temperatures normally encountered in the Navy. *Figure 2-3* illustrates the influence of air circulation upon losses. While the loss from the insulated surface increases with an increase in air circulation, it is by no means proportional to that from the non-insulated surface.

When using mechanical refrigeration equipment, the reduction of the temperature of the substance being cooled is accomplished by a comparatively expensive process. The walls of the cold room are surrounded by warmer air, therefore, a particularly effective insulation is necessary to prevent the return, to the cooled region, of the heat units which have been removed.

Whether heating or refrigerating is involved, insulation is essential to economical operation

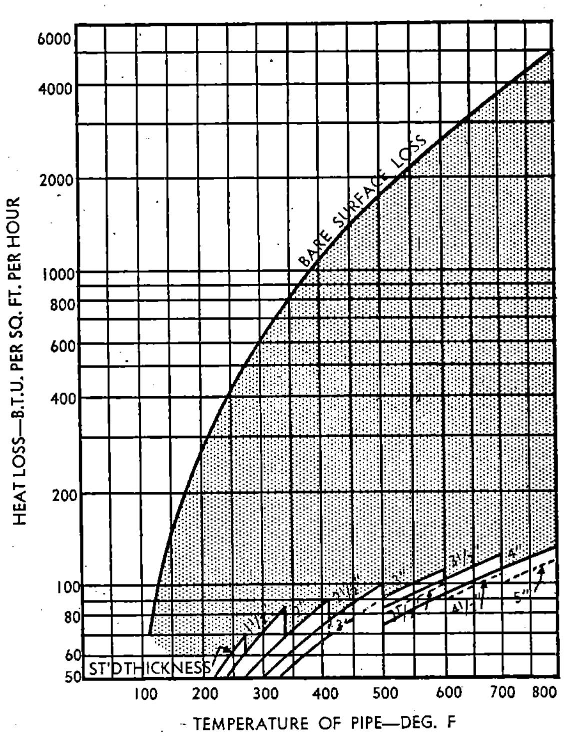


FIG. 2-2. Curves Showing Effect of Insulation Upon Heat Loss.

and, through heat saving, pays for itself many times.

2-2. THEORY OF INSULATION.

The basic theory of heat transfer (assuming uniform temperature conditions of both the warmer and the cooler surfaces) may be likened, in conception, to Ohm's law; that is to say, heat flow varies directly as the potential and inversely as the resistance. Thus, the flow through a heat barrier depends upon the difference in temperatures (potential) of the two sides of the barrier and upon its resistance. The resistance is composed of that due to the composition of the barrier plus a resistance of each surface, the surface resistance of the warm side of the insulation being usually neglected.

The heat radiated from a hot surface is proportional to with the difference of the fourth powers of the absolute temperatures of the surface and the surrounding (not adjacent) air. It is also dependent on the surface resistance, which is influenced by the color, texture, and degree of roughness of the surface. A bright smooth surface offers a greater surface reluctance to the radiation of heat than a dull or matte surface. This fact explains why the loss will be less when the insulation is covered with a bright metal jacket than it would if such metal jacket were not used; also why it is quite possible to change the surface of a body with paint and reduce, under certain conditions, the radiation loss.

2-3. EFFECT OF AIR CIRCULATION.

Surface radiation loss depends upon the relative temperature conditions at the surface. Air circulation increases this radiation loss by continuously providing a supply of relatively cool air at the outer surface. In the case of bare surfaces, the result is a marked increase in loss. The difference in the effects of air velocity on bare and insulated surfaces is shown in *Fig. 2-3.*

The foregoing discussion of the effect of air circulation upon heat losses applies to cases where the insulation is properly sealed. If conditions are such that the air may circulate through cracks and crevices in the insulation, the increases may be far greater; hence the importance of maintaining a tight seal on insulation, particularly when the unit insulated is subjected to air circulation.

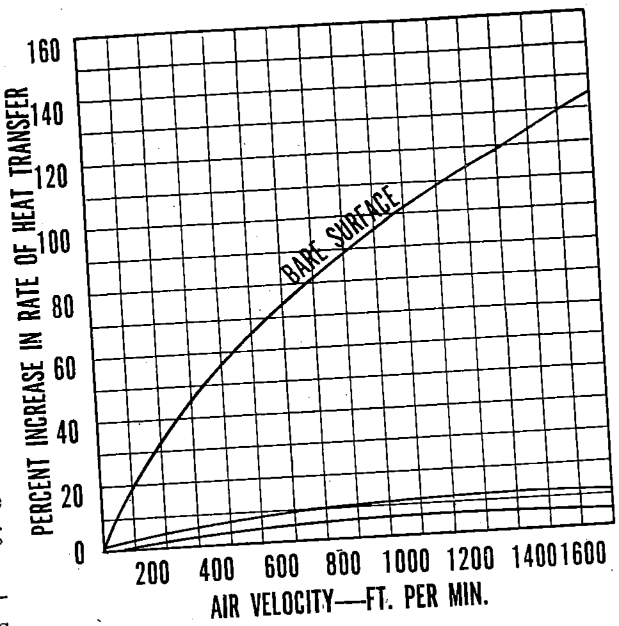


FIG. 2-3. Increase in Heat Losses Due to Air Circulation.

2-4. COMPUTING HEAT LOSSES AND INSULATING EFFICIENCY.

A general practice is first to establish the loss without insulation and then to compute the loss through the proposed insulation in order to arrive at the amount saved. The efficiency of an insulation depends upon the percentage of the bare surface loss which it saves, and is obtained by subtracting the heat loss through the insulation from the heat loss of a corresponding uninsulated surface and dividing the difference by the uninsulated surface loss thus,

$$\text{Efficiency} = \frac{\text{Uninsulated surface heat loss} - \text{insulated surface heat loss}}{\text{Uninsulated surface heat loss}}.$$

The heat losses for uninsulated surfaces have been established for various temperatures and corrections determined for the substantial increase in loss due to air velocities. The tabular losses from bare surfaces must always be corrected for air velocities met in conditions under consideration.

For arriving at the loss through insulation two methods are practical; (1) formulas from any good engineering handbook can be used, if the conductivities for the mean temperatures involved are at hand; (2) the tables of efficiencies

for the particular material can be used. Efficiency data are usually available from the manufacturer of the insulation or from technical references.

2-5. INSULATING MATERIALS.

Insulation covers a wide range, from extremely low temperatures met in refrigerating plants to the very high temperatures found in boiler furnaces. No one material could possibly meet all such conditions with maximum efficiency. In general, an insulation is designed to be adaptable for a specific temperature range and set of conditions.

For low temperatures, cork, or rock wool is used. For high temperatures, recourse is had to basic minerals, such as asbestos, carbonate of magnesia, diatomaceous earth, argillaceous limestone, mica, aluminum foil, and fibrous glass. Diatomaceous silica, because of its high degree of refractoriness, forms the base of practically every high temperature insulating material in use today.

These materials are processed so as to produce a maximum number of minute air voids and then are formed into sheets, blocks, cylindrical sections or cements. The processing may be an aeration of calcined material, as with magnesia; or a calcining and fibering operation, as with rock wool or fibrous glass; or an explosion process, as is used in making expanded mica. In any case the objective is to secure a finished material with a multitude of completely enclosed microscopic air cells, to avoid conduction, radiation, and convection in the insulation itself. The small size of these cells may be visualized to some extent when it is considered that there are from 40 to 50 million individual cells per cubic inch in some of the natural minerals.

Exhaustive tests, under conditions approximating those in the naval service, prove the suitability of a material. In the final analysis, the objective is sustained efficiency. To be adaptable to a set of conditions, a material must possess not only a high initial efficiency but also the quality of retaining this original efficiency over a long period of service. In addition to a low initial conductivity, the following requirements for a good insulating material are listed:

(a) Ability to withstand the highest or lowest temperature to which it might be subjected in service, without impairment of insulating value.

(b) Sufficient structural strength to withstand handling during application and the mechanical shocks and vibrations incident to service conditions, without disintegration, settling, or deforming;

(c) Stability in chemical and insulation characteristics;

(d) For boiler wall and furnace insulation, low heat capacity (specific heat) to minimize starting-up time required;

(e) Ease of application and repair; and

(f) Must not constitute a hazard in case of fire.

2-6. APPLICATION OF INSULATION.

All pipe covering sections or segments should be tightly butted at joints and secured by adequate wire loops, metal bands, or lacing. Block insulation is secured by one-eighth inch steel wire and galvanized mesh wire or expanded metal lattice. Insulating cement is used to fill all crevices, to smooth all surfaces, and to coat completely any wire netting, before the final lagging is applied.

Moisture-proofing of insulation over heated surfaces is important. Moisture impairs any insulation and, even though the temperature of the insulation dries off the moisture, the heat loss is increased because of this evaporation. Over low temperature surfaces, the moisture-proofing of insulation is very important and, at very low temperatures, the insulation should be air-sealed. Moisture in outside air which is drawn into low temperature insulation condenses and freezes, materially lessening the efficiency and eventually causing disintegration.

The insulation of flanges, fittings, and valves presents a somewhat different problem than that of piping; however, the same materials may be employed as on adjacent piping. For example, on sizes 4 inches and larger, the bodies of flanged fittings and valves, the entire surface of a threaded fitting, the entire surface up to the bonnet of screwed valves, and flanges of all pipe sizes where flange insulation is to be of the permanent type, may be insulated with block insulation one-half inch thinner than the insulation on the adjacent piping. Insulating cement is then applied to make the total thickness of insulation on the valve or fitting equal to that on the adjacent piping. Pipe insulation should be stopped short of all flanges and beveled off to permit removal of

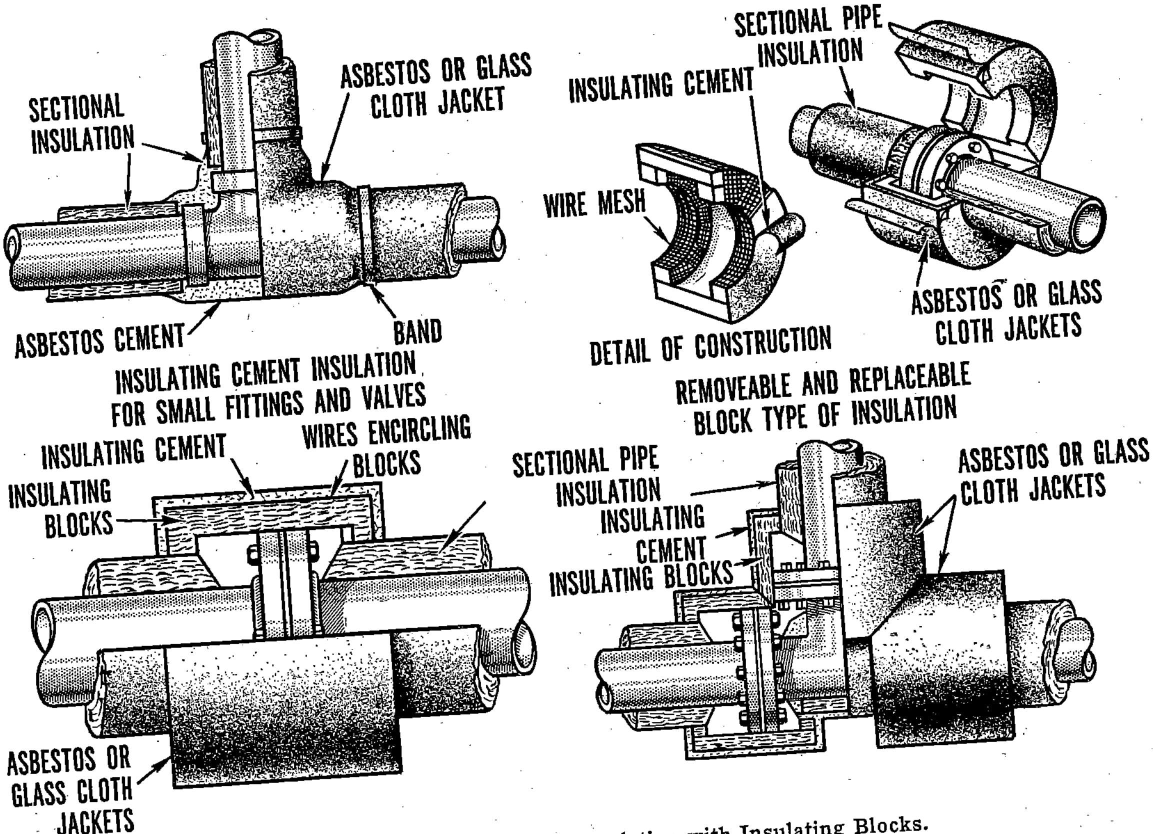


FIG. 2-4. Permanent Type of Insulation with Insulating Blocks.

flange bolts when necessary. On piping $3\frac{1}{2}$ inches and smaller, in place of blocks and cement, the entire insulation of flanged and screwed fittings and valves may consist of thermal insulating cement of the same thickness as that of the adjacent piping. Flanges, the insulation of which is required to be of the removable type, should be insulated with (1) asbestos felt pads, (2) sectional pipe insulation of the same thickness as the insulation on the adjacent piping, or (3) block insulation one-half inch thinner than the insulation on the adjacent piping, covered with one-half inch of insulating cement. *Figure 2-4* illustrates several types of insulation for flanges and fittings.

2-7. FORMS OF SERVICE MATERIALS.

It is the purpose of this article to present briefly the forms of insulating materials used in the naval service in cases where the temperature encountered is not above 1500°F. Refractory and insulating materials employed to withstand the high temperatures encountered in boiler furnaces is discussed in Part I, *Naval Boilers*. The most common types of insulation used for other purposes found in the 1500°F. and below range are listed below and later discussed in brief:

(1) Magnesia and asbestos mixtures,
(2) Sectional and segmental molded insulation,
(3) Asbestos
(4) Mineral wool (Rock wool),
(5) Aluminum foil,
(6) Insulating cements,
(7) Asbestos pads and blankets,
(8) Glass fiber pads,
(9) Asbestos tapes, and
(10) Cork in sectional block or compressed form.

(1) A mixture of **magnesia and asbestos** containing about 85 percent magnesia predominated in the field of heat insulating materials until the advent of steam temperatures in excess of 500°F. At temperatures above 500°F. this material calcines and decomposes. Its cheapness, lightness, low conductivity, and the ease with which it can be applied in various forms have all been factors for the retention of its use in the naval service. It is obtainable in plaster form, in blocks and in cy-

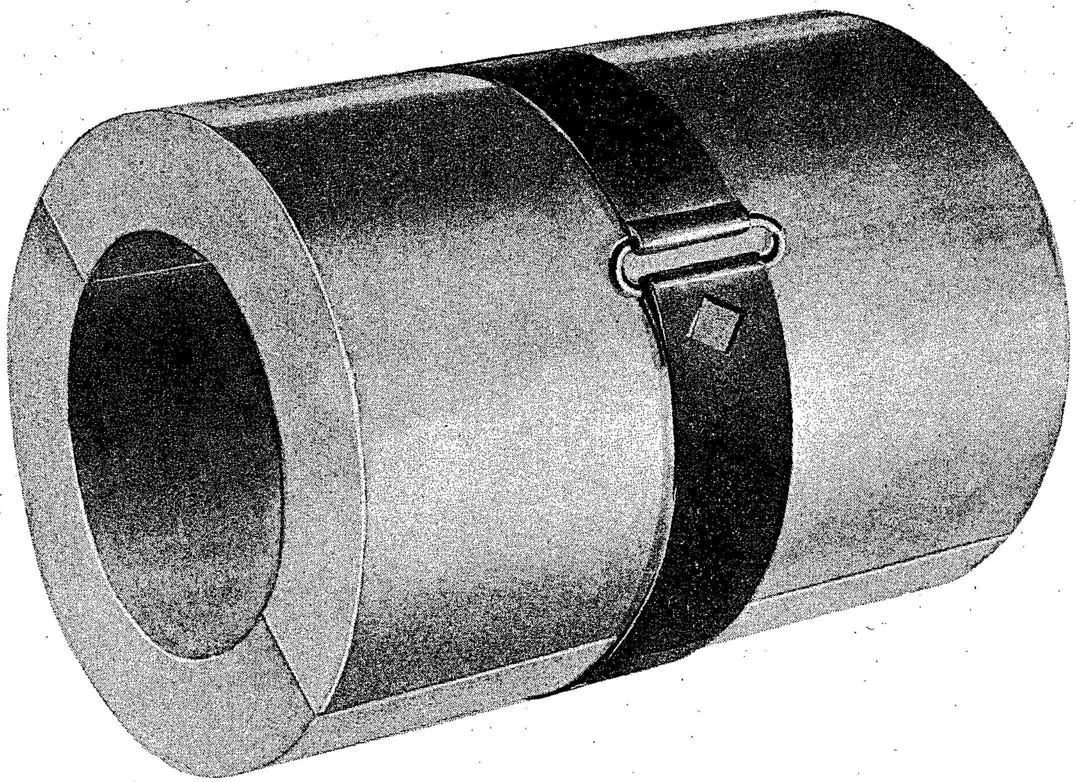


FIG. 2-5. Magnesia and Asbestos.

lindrical sections for standardized pipe sizes, a section of which is shown in *Fig. 2-5*.

(2) The **diatomaceous earth** type materials are generally composed of large percentages of diatomaceous earth and magnesium or calcium carbonates bonded together with small percentages of asbestos fibers. Though these materials are heavier, more expensive, and do not possess as high heat insulating properties, their high heat resisting properties allow their use up to 1500°F. Whenever practical, especially for pipe coverings, the material is made up with an inner layer of the heavier diatomaceous materials and an outer layer of the magnesia type insulation above discussed in order to lighten the over-all weight of the material.

(3) Asbestos. The molded insulation of long length asbestos fibers is suitable for temperatures up to 850°F. and is employed primarily for pipe covering. It is cheaper than the diatomaceous earth type, is lighter, possesses low conductivity and is durable and rugged.

(4) Mineral wool or rock wool is a fiber made by sending a blast of steam through molten slag or rock. It is resistant to moisture. Mineral wools are used in wire reenforced pads as shown in *Fig. 2-6* for insulating large areas.

(5) Aluminum foil coverings were gaining favor in the insulation field prior to the war but the critical nature of the material arrested their use. Strange as it seems that metal can be used successfully as an insulator, such is the case. It is manufactured for use as an insulator in long thin sheets of approximately 0.003″ thickness. It is first crumpled by hand and then applied in layers which are held apart approximately $\frac{3}{8}$″ solely by the crumpling. As shown in *Fig. 2-7* a sheet metal covering encases the assembly, the casing being held clear of the piping by the sheet metal towers. The cost of application in this manner is very high.

For its insulating value in practical installations, aluminum foil depends on the reluctance of a bright surface to absorb and radiate heat, and in part, on the opposition to convection currents, presented by the small air cells formed between adjoining layers of the crumpled foil. Though aluminum foil insulation is much lighter than other types described, the advantage is largely lost in the weight of the protecting sheathing and

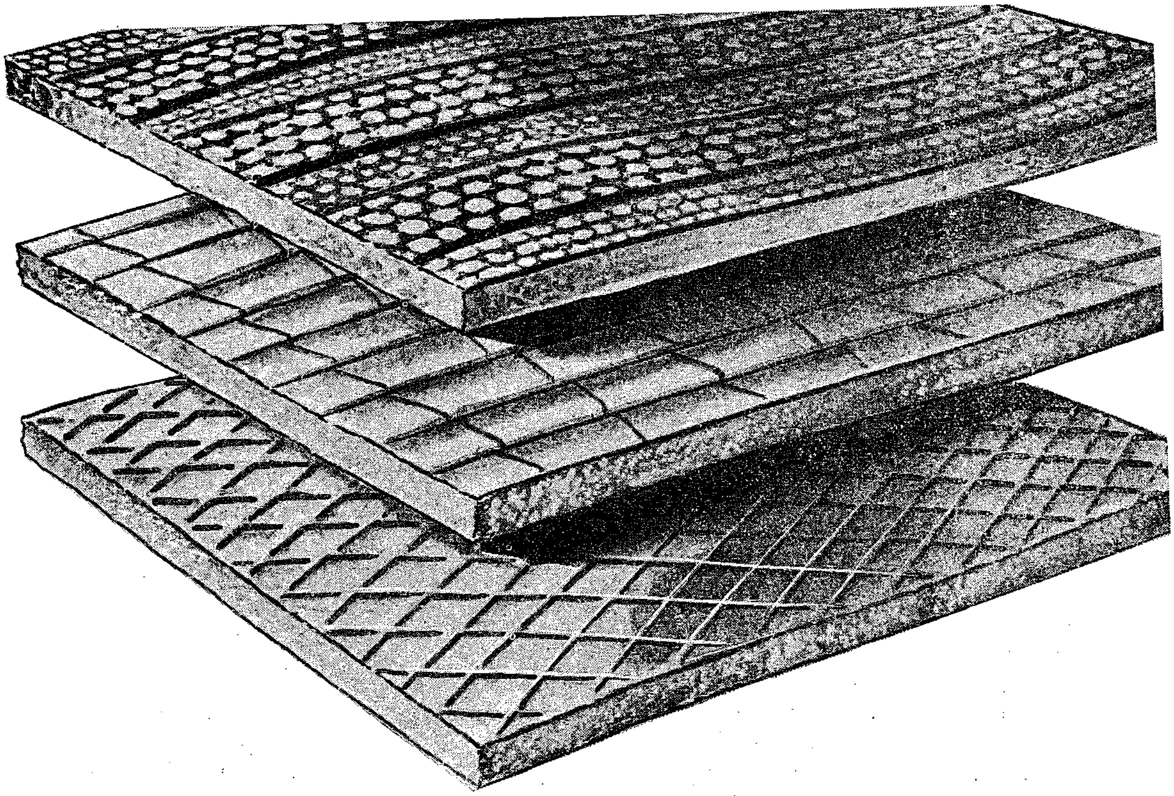


FIG. 2-6. Mineral Wool Blankets.

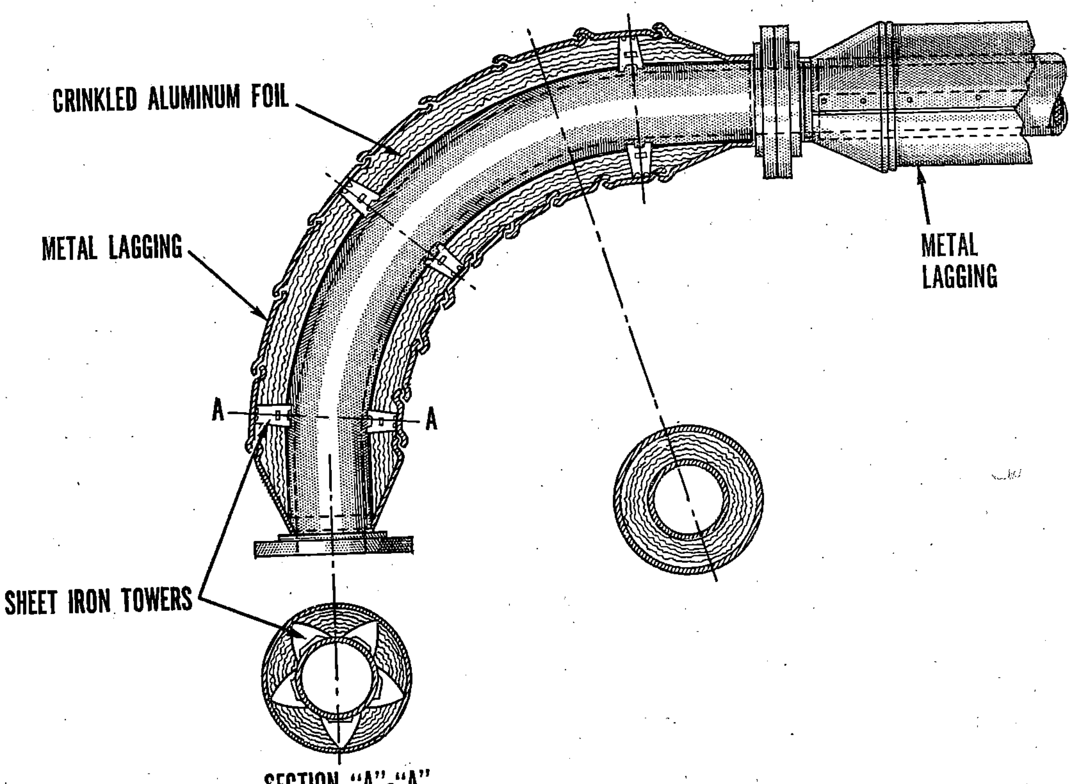


FIG. 2-7. Method of Installing Aluminum Foil Insulation on High Temperature Steam Piping.

its accessories. As the melting point of aluminum is 1200°F. its use is limited to a designed operating temperature at 850°F.

(6) Insulating cements are made from many different materials which differ widely among themselves as to heat conductivity, weight and physical characteristics. They are uniformly less efficient than the other high-temperature coverings, but their suitability for patch-work and emergency repairs and the covering of small irregular surfaces, justifies their use. Cements also find a ready use for surface finish over block or sheet forms of insulation, to seal all joints between the blocks and to provide a smooth, attractive finish over which asbestos or glass cloth lagging may be applied (*Fig. 2-4*). They are especially suitable, also, for insulating irregular surfaces such as valves, flanges, and pipe fittings. They may be grouped as to their basic constituents as follows:

(a) Magnesia plastic cement,
(b) Diatomaceous earth cements,
(c) Mineral wool cements,
(d) Asbestos finishing cements.

(7) The use of **asbestos pads and blankets** is important in the insulation of large irregular surfaces such as turbine casings and for insulating flanges or valves which must be taken down fairly often.

The pads are made up of woven asbestos cloth in envelope form, filled with long asbestos fibers and tufted at close intervals with wire inserted asbestos yarn. These pads may be tailored to fit any shape and the outer surface of each section of material is generally fitted with metal hooks which make possible easy installation or removal.

Blankets are composed of rovings of long asbestos fibers. The rovings are made of desired thickness, laid side by side and fastened together with wire inserted asbestos yarn. These blankets are generally manufactured about 1″ thick and 40″ wide. Easy installation or removal is here again facilitated by the use of metal lacing hooks.

(8) Glass in fibrous form, generally made up in the form of pressed slabs, is widely used in insulating hull spaces and living quarters. The glass fibers composing the slabs are 4 or more inches in length and 0.0008″ to 0.0005″ in thickness. These slabs have low moisture absorbing qualities and offer no sustenance to insects, vermin, fungus growth, or fire. They are about an inch in thickness, are cut to shape, then secured in place by mechanical fasteners such as quilting pins and covered with glass cloth facing and stripping tape which is held in place by fire resistant adhesive cement.

(9) Asbestos tapes are employed in the naval service for the purpose of covering ½-inch and smaller size piping with curves and bends. These materials possess relatively poor insulating properties and are used primarily to reduce fire hazard and to protect personnel. Tapes have been manufactured suitable for use at temperatures up to 750°F.

(10) Cork in block section or compressed board form coated with a special fire retardant cover is used where authorized for temperatures below 50°F. Its authorized use is confined to a few areas such as refrigeration spaces where its use will not cause a serious fire hazard. Molded cork pipe-covering treated with a fire retardant compound is used on refrigerant piping.

2-8. PACKING.

The primary purpose of packing is to seal joints of machinery and equipment against leakage. There are four principal types of joints with which packing is employed as follows:

(1) Those which slide, such as piston rods, pistons and expansion joints,
(2) Those which rotate, such as shafts,
(3) Those which operate helically and intermittently, such as valve stems; and
(4) Those which are fixed, such as flanges and bonnets.

Of these the moving joints offer the greatest difficulty, since it is necessary to seal against leakage without causing excessive friction, undue wear of the moving part, and early failure of the packing.

In the days of low pressure power plants, packing materials and packing spaces were given but little consideration. In many of the installations, packing spaces and methods had the appearance of being emergency measures added to the machinery to correct a situation which was giving trouble. The original packing materials which gave the best performance were in the form of hemp rope and leather. Later, to these were added textile fibers and fabrics, asbestos fibers; then rubber, a combination of rubber and textiles; and later, metals. Today we may choose our

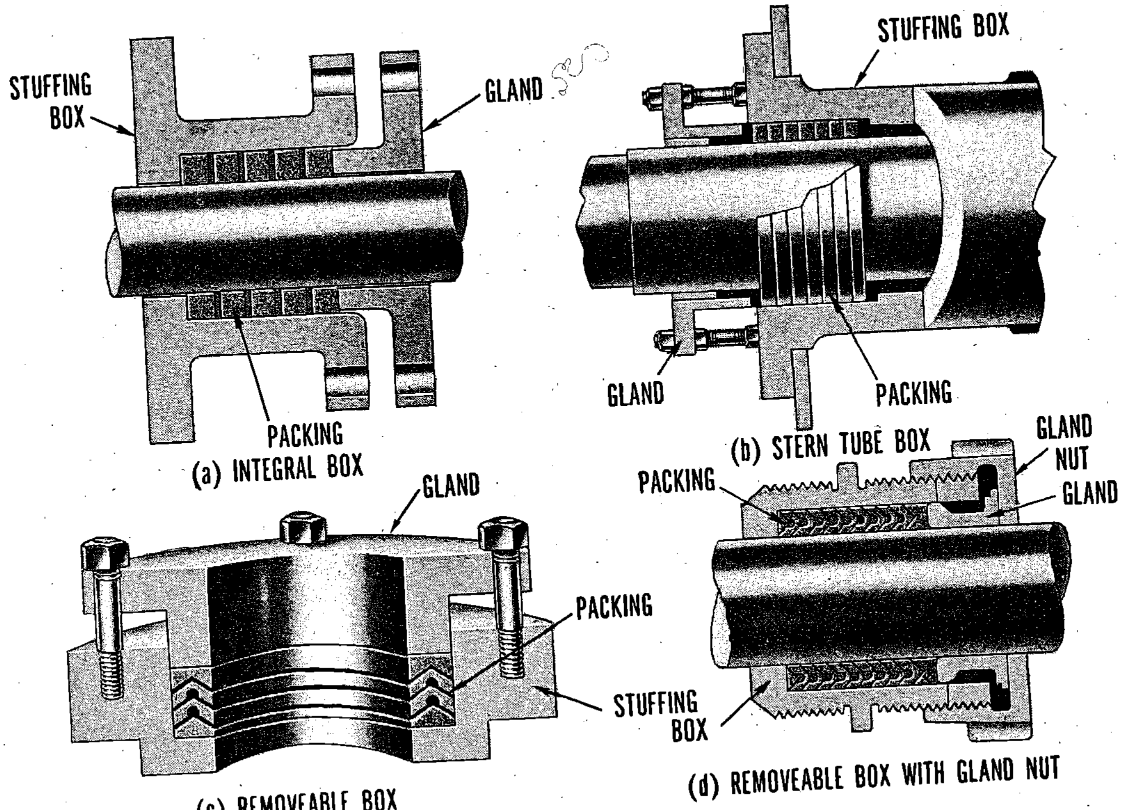


FIG. 2-8. Stuffing Boxes.

packing from almost endless variations of these basic materials.

At one time there were more than 60 different types of packing approved for naval service use. Many of the types were of such close similarity that the selection of the proper packing for a specific condition was a problem for the operating engineer. The situation has been relieved to a great extent, through standardization of the packing by the assignment of Navy symbol numbers. Each symbol number has four digits; the first digit indicates the class of service, whether for a moving joint or a fixed joint. The numeral "1" indicates a moving joint, such as moving rods, shafts, valve stems, etc. The numeral "2" indicates that the packing is for a fixed joint such as flanges and bonnets. The second digit indicates the predominant material of which the packing is composed, such as asbestos, vegetable fiber, rubber, metal, etc. The third and fourth digits indicate the different styles or forms of packing made of the predominant material. The correct type packing for a specific service can be determined by reference to the packing and gasket table in Chapter 95 of the *Bureau of Ships Manual.*

Packing is inserted in stuffing boxes (*Fig. 2-8*) which, generally speaking, consist of cavities so located around valve stems, rotating shafts, or reciprocating pump rods that they can be "stuffed" with a packing material which is compressed as necessary and held in place by flanged and bolted or threaded gland bushings.

Coils, rings, spirals, and molded rings (*Fig. 2-9*) are the most common forms in which packing is prepared commercially. The materials shown are only a few of the many employed. For a long time high pressure asbestos rod packing was used almost exclusively for sealing moving steam joints (rods, valve stems, etc.). Its use for sealing the joints of high pressure high temperature valve stems has been superseded by wire inserted square braided asbestos (up to 400 p.s.i. and 700°F.) and by plastic non-metallic, asbestos packing encased in a braided wire covering (up to 650 p.s.i. and 850°F.). The square braided asbes-

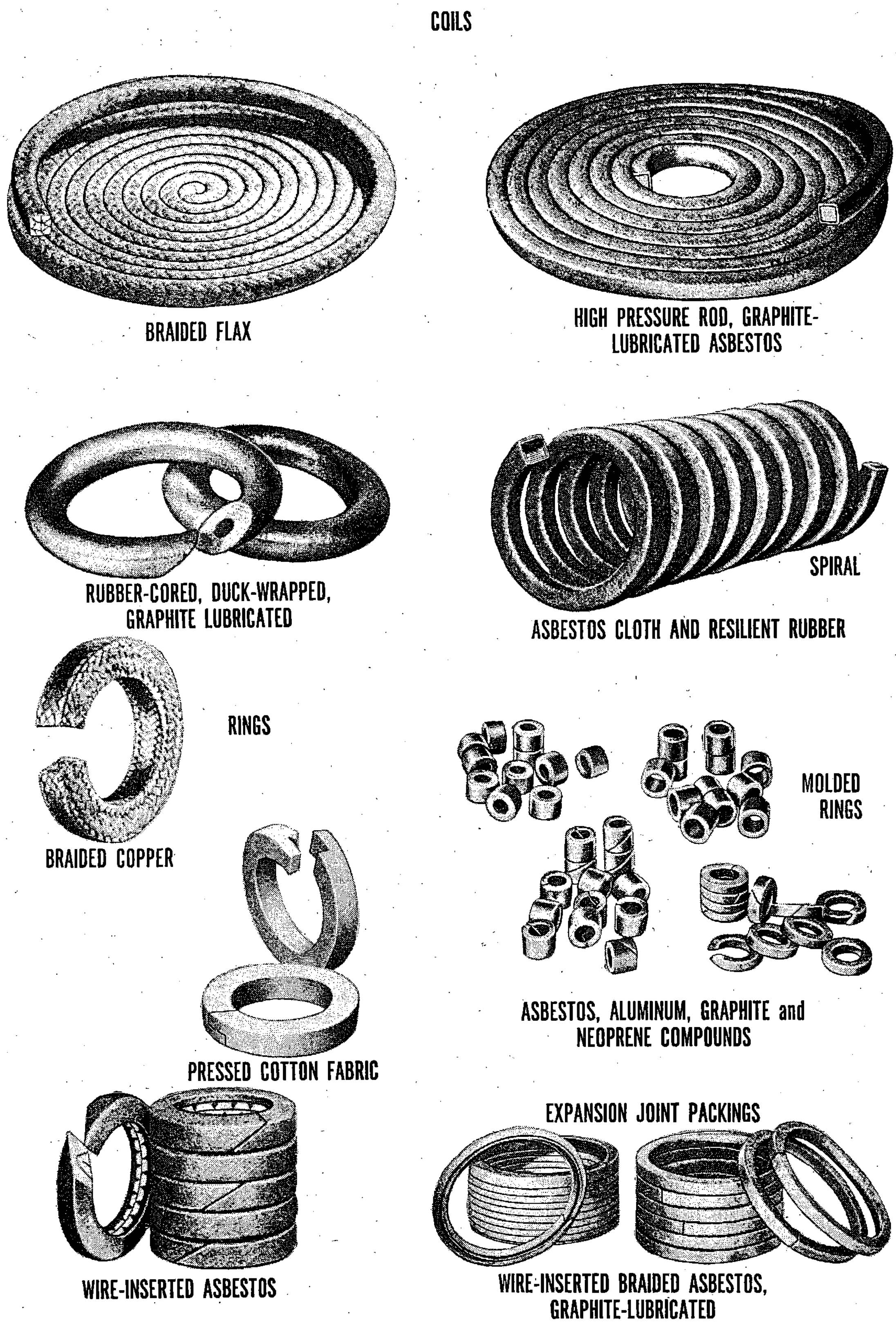


FIG. 2-9. Packing.

tos packing is composed of 90 percent asbestos with brass or copper wire inserted yarns, and a high temperature lubricant. The plastic nonmetallic, asbestos and wire jacket type is composed of a plastic core of asbestos fibers, graphite, and a binder, encased in a braided monel wire jacket. These metal inserts or jackets tend to act as a bearing surface for the packing, cutting down friction and increasing the life of the packing.

For high pressure hydraulic service such as steering gears and elevator shafts a "Vee" type packing (*Fig. 2-8c* and *2-8d*) is used. It is composed of laminated plies of fabrics impregnated with a heat and oil resisting compound and so designed that the shape permits the plies to expand under pressure.

The sealing of rotating joints has brought about more serious consideration of the packing problem. It is possible with this type of joint, for the packing to create sufficient friction to prevent the machine or apparatus from operating. In the sliding type of joint, the heat of friction created by the packing is dissipated through the moving part of the joint. Such, however, is not the case in the rotating type of joint. Hence, the heat of friction created by the packing will build up on the wearing faces of the packing and the shaft unless other means are provided for its dissipation. This is accomplished through the use of packings composed of materials which have high heat conductivity properties and through the allowance of leakage. It is of particularly importance in packing rotating joints that pressure applied to the packing be kept at a minimum consistent with permissible leakage from the joint. The packings generally employed in rotating joints of pumps and small, low speed, steam turbines, are flexible metallic and plastic metallic types. In the rotating joints of high speed turbines, labyrinth glands and/or carbon ring packing is used.

The flexible metallic packing is composed of metal foil, ribbons or strands, wrapped, crimped, twisted and braided into a continuous strip. The plastic metallic packings are composed of admixtures of particles of metal, asbestos fibers, graphite, and binders encased in a loosely woven cotton or metal jacket.

The carbon packings used in the rotating joints of steam turbines are composed of three or more ring segments made of refined coke and/or graphite held together by a suitable binder. The ring is machined to the desired dimensions, the flat sides being parallel and smooth, and the inner surface is ground true and at right angles to the sides. The segments are held together by means of a

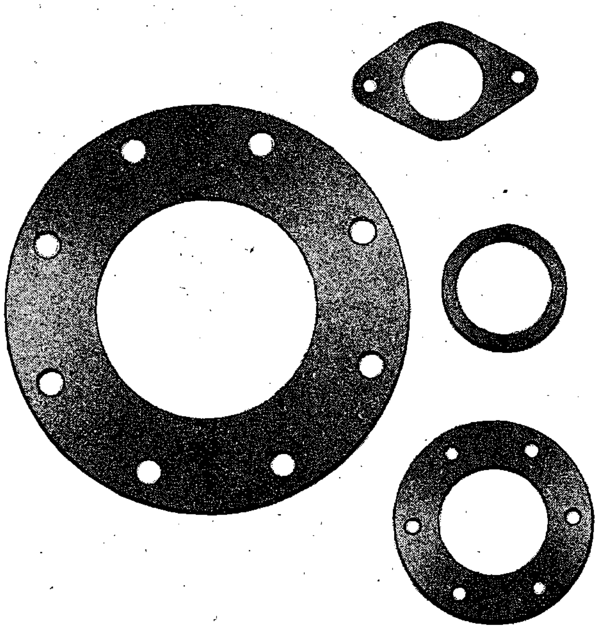


FIG. 2-10. Sheet Asbestos Gaskets.

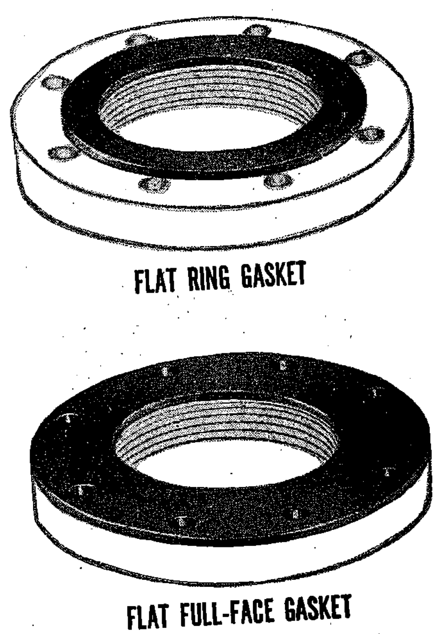


FIG. 2-11. Plained-Faced Metal Gaskets.

coil spring which lies in a groove in the outer periphery of each packing ring.

2-9. PACKING FOR FIXED JOINTS.

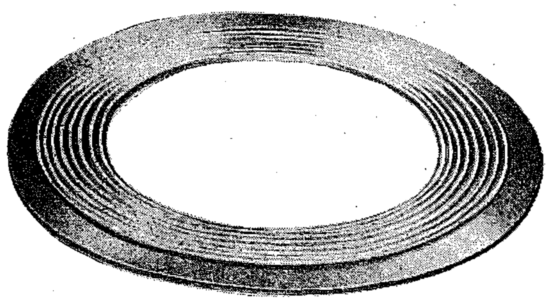
The sealing of fixed steam joints, until recent years, was performed in a satisfactory manner through the use of gaskets made from compressed asbestos sheet packing (*Fig. 2-10*). This packing is composed of approximately 85 percent asbestos fibers and 15 percent rubber compounds. In view of the relatively high rubber content of the material the use of this type of gasket is limited by temperature considerations. The present day high temperature steam, together with a lack of sufficient strength at elevated temperatures, results in the failure of such gaskets. For high temperatures, the use of metallic or semi-metallic gaskets is considered to be necessary.

At the present time there are three types of metallic or semi-metallic gaskets in use in the service.

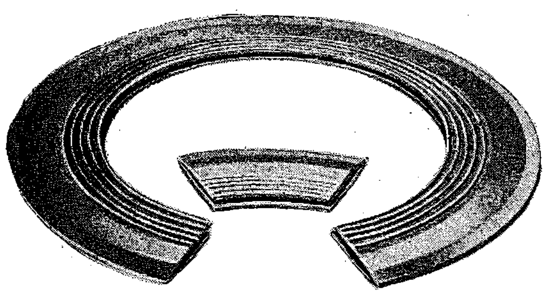
(1) A flat-ring or plain faced gasket (*Fig. 2-11*). These metal gaskets are made of monel metal or soft iron to specified shapes and sizes. A variation of this type is the ring gasket shown.

(2) A serrated-face gasket also made from monel or soft iron (*Fig. 2-12*). The raised serrations help to make a better seal at the piping flange joints and give the gasket some resiliency. A variation of the serrated gasket also shown is the expanding serrated gasket (*Fig. 2-12b*). When this gasket is used, line pressure acts between the plates to force the serrated faces tighter against the adjoining flange. This is a relatively new type having limited service experience.

(3) The asbestos-metallic, spiral-wound gasket (*Fig. 2-13*) which is composed of alternate layers or plies of dove-tailed metal ribbon and strips of asbestos felting spirally wound, ply upon ply, until the desired diameter is obtained. The metal ribbon is a single stainless steel strip 0.″007 to 0.″015 thick and 0.″175 wide after forming. For the purpose of interlocking the metal strip, the asbestos felting may be in the form of two separate strips wound to conform with the flats of the metal strip on both sides of the dove-tailed section. The end of the metal strip is made fast by crimping and welding to the preceding ply. In order to prevent a complete blowout, if failure



(a) SINGLE-PLATE TYPE



(b) EXPANDING (DOUBLE-PLATE) TYPE

FIG. 2-12. Serrated Metal Gaskets.

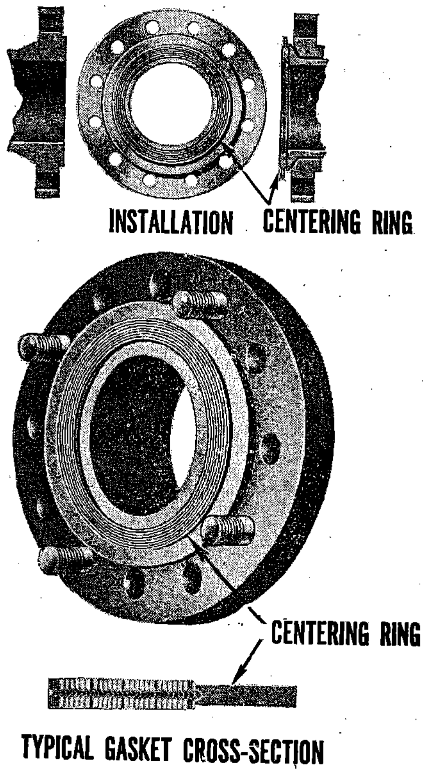


FIG. 2-13. Metallic-Asbestos Spiral-Wound Gasket.

of the gasket should occur, a solid steel ring thinner than the spiral wound section is attached to the outer periphery of the gasket. This ring is about 0.″125 inch thick and acts as a bolting guide and a centering ring, as well as a reenforcement. The spiral wound gaskets are so manufactured that, with proper bolt tension, the gasket will compress to 0.″135 in thickness. This leaves a total of clearance 0.″010 between the flange faces and the centering ring. The gasket can be compressed to the thickness of the centering ring without being damaged.

A property which a gasket should possess to maintain a tight joint is resiliency. In tests conducted at the Naval Engineering Experiment Station it was found that the plain-faced type gasket depended entirely upon the bolt stress for maintaining tightness of the joint; hence when the bolt stress was reduced below a certain amount through elongation of the bolts and through sudden change in temperature conditions, leakage occurred from the joint. The same was found to some extent with the ordinary serrated face type gasket. The spiral wound, semi-metallic type gasket performed satisfactorily, and the bolt stresses required to obtain tightness of the joint were less than those required with the plain and serrated types of gasket. Bolt stresses required for the expanding serrated type gasket should be materially less.

Gaskets are designed in many variations of the three principal types above listed. In making up fixed joints, the proper gasket for any particular service can be determined by reference to the packing and gasket table, Chapter 95, of the *Bureau of Ships Manual*.